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CLEVIS DESIGN FOR COMPACT TENSION SPECIMENS USED IN PLANE-STRAIN FRACTURE TOUGHNESS TESTING

by Raymond T. Bubsey, Melvin H. Jones, and William F. Brown, Jr.

Lewis Research Center
Cleveland, Ohio

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ABSTRACT

An experimental investigation was made of friction effects in a conventional round-hole clevis used for testing compact tension fracture toughness specimens. The results showed measured plane-strain fracture toughness K_{Ic} values could be too high by about 10 percent when the loading-pin-to-hole clearances are only a few thousandths of an inch. Lubrication was found to have only a small effect. Increasing the pin clearance reduces the friction effects, but uncertainties in the initial position of the load axis with respect to the slot tip (equivalent to variation in crack length to width ratio a/W) result in a possible spread in K_{Ic} values of nearly 5 percent. A new clevis design is described which greatly minimizes the errors caused by friction and variations in effective a/W. This design is proportioned to permit testing of materials having a wide range of toughness and yield strength.

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SUMMARY

An experimental investigation was made of friction effects in a conventional round-hole clevis used for testing compact tension fracture toughness specimens. The results showed measured plane-strain fracture toughness K_{Ic} values could be too high by about 10 percent when the loading pin-to-hole clearances are only a few thousandths of an inch. Lubrication was found to have only a small effect. Increasing the pin clearance reduces the friction effects, but uncertainties in the initial position of the load axis with respect to the slot tip (equivalent to variation in crack length to width ratio a/W) result in a possible spread in K_{Ic} values of nearly 5 percent.

A new clevis design is described which greatly minimizes the errors caused by friction and variations in effective a/W. This design is proportioned to permit testing of materials having a wide range of toughness and yield strength.

INTRODUCTION

In 1965, Manjoine (ref. 1) proposed the use of an eccentrically loaded, edge-notched plate specimen of very compact design for the measurement of plane-strain fracture toughness K_{Ic}. Various modifications of this basic design have been proposed (refs. 2 and 3), most of which employ pin loading. Recently, the ASTM Committee on Fracture Testing of Metals has proposed a method for K_{Ic} testing using a fatigue-cracked, pin-loaded specimen of this type, referred to as a compact tension specimen.

When testing pin-loaded edge-cracked specimens, it has been general practice to employ a round-hole clevis with loading pins that fit the specimen loading holes and clevis holes with only a few thousandths of an inch clearance. Under these conditions, nonlinearities are frequently observed in the load-displacement records. This problem

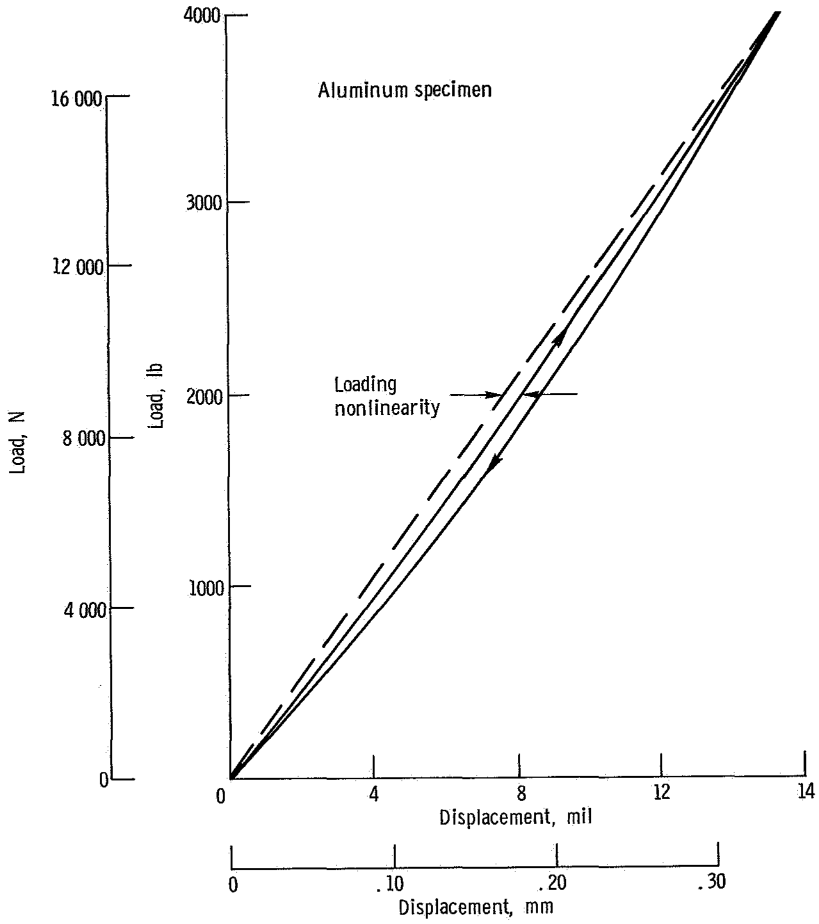


Figure 1. - Typical load-displacement record using tight-fitting pins in conventional clevis. Specimen and clevis hole diameter, 0.602 inch (1.53 cm); pin diameter, 0.596 inch (1.51 cm).

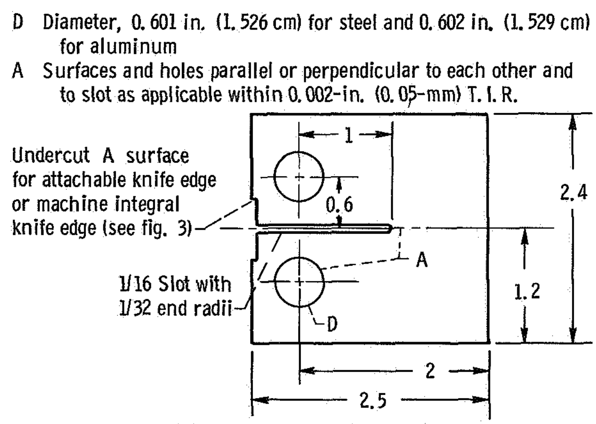
is illustrated in figure 1, which shows a load-displacement record obtained on a compact tension specimen using experimental procedures described in INSTRUMENTATION AND TESTING. The clearances were small, and the load-displacement curve exhibits an upward curvature during loading and a hysteresis loop on unloading. These nonlinearities are primarily associated with frictional resistance, which increases the load necessary for a given displacement. While it is often a practice to lubricate the pins, it is shown later (table I) that the beneficial effects of lubricants are very small.

As pointed out by Pook and Dixon (ref. 4) and by Pook (ref. 5), the pin friction introduces a bending moment which opposes the rotation of the specimen about the pins and results in measured K_{Ic} values which are higher than would be determined without the friction. Based on an assumed reasonable friction coefficient, these authors suggest that the error in K_{Ic} could be 5 percent for centerline-loaded edge-cracked tension specimens with $a/W = 0.5$.

The present investigation was conducted to determine the possible errors in K_{Ic} measurement that could be associated with friction effects in a conventional round-hole clevis, and to arrive at a clevis design which would minimize these errors. Tests were made on compact tension specimens of standard proportions with two clevis designs using pins of various diameters. In addition, a few tests were made to determine the influence of misalinement in a direction parallel to the pin axis.

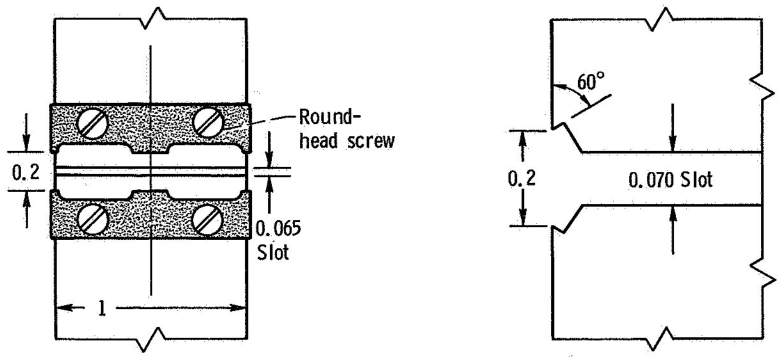
SPECIMENS AND CLEVISES

Two compact tension specimens of standard proportions (fig. 2) were used. One was made from 300-grade maraging steel aged to a yield strength of 285 ksi (1965 MN/m^2) and the other from 2024 T-351 aluminum alloy. The specimens were provided with a 1/16-inch (1.6-mm) slot terminating in a 1/32-inch (0.8-mm) radius. Integral knife edges were used to fix a cantilever displacement gage (ref. 6) to the steel specimen. The aluminum specimen was provided with attachable steel knife edges which referenced



U.S. Customary Units, in.	SI Equivalent Units, mm
1/32	0.8
1/16	1.6
0.6	15.2
1	25.4
1.2	30.5
2	50.8
2.4	61.0
2.5	63.5

Figure 2. - Steel or aluminum compact tension specimen 1-inch (2.54-cm) thick and of standard proportions. (All dimensions are in inches.)



(a) Aluminum specimen; 60° attachable knife edges flush with specimen face and parallel to slot plane within 0.002-in. (0.05-mm) T.I.R.

(b) Steel specimen; integral knife edges parallel to slot plane within 0.002-in. (0.05-mm) T.I.R.

U.S. Customary Units, in.	SI Equivalent Units, mm
0.065	1.65
.070	1.78
.2	5.08
1	25.4

Figure 3. - Knife edges for displacement gage attachment. (All dimensions are in inches.)

shoulders on the specimen faces (see figs. 2 and 3). These knife edges (fig. 3(a)) were so designed that the edge and center displacements could be measured independently. Specimen machining tolerances were held within close limits to minimize misalinement inherent to the specimen.

The first series of tests was made using a clevis of conventional design having 0.602-inch- (1.53-cm-) diameter loading-pin holes. Following the tests with this conventional clevis, a square-hole clevis was designed in an attempt to overcome the observed deficiencies associated with the conventional type. This modified design was provided with holes in the form of 0.630-inch (1.60-cm) round-cornered squares. Both clevises were made from fully aged 300-grade maraging steel to the general proportions and tolerances used for the final design (see fig. 13). A series of fully hardened 300-grade maraging steel loading pins was ground to diameters of 0.599, 0.596, 0.590, 0.580, 0.560, and 0.500 inch (1.52, 1.51, 1.50, 1.47, 1.42, 1.27 cm). These provided clearances of from 0.003 to 0.102 inch (0.076 to 2.59 mm) with the round-hole clevis.

A special loading fixture permitted lateral misalinement of the clevis with respect to the loading axis. As shown in figure 4, this misalinement was in the direction of the loading-pin axes and could be controlled by the use of shims.

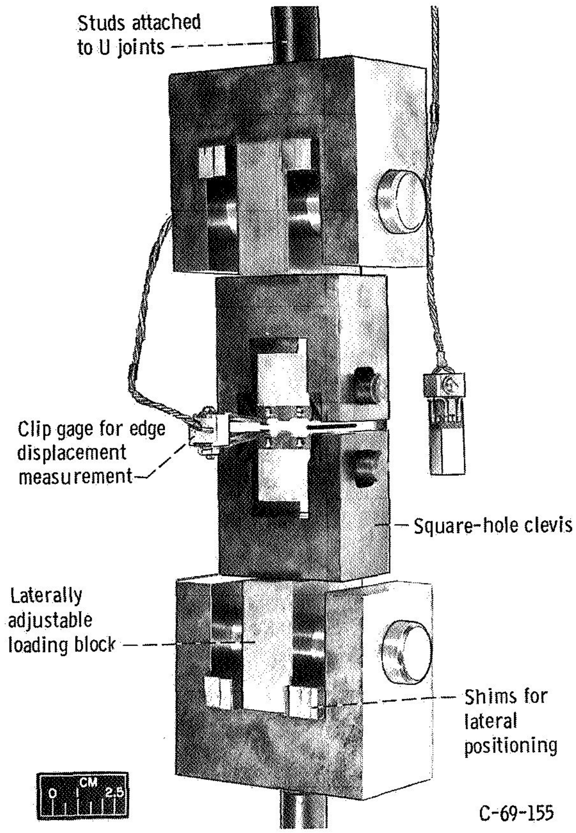


Figure 4. - Special loading fixture for lateral misalinement tests.

INSTRUMENTATION AND TESTING

A load cell in series with the specimen provided a signal to one axis of an X-Y plotter. The other axis of the plotter was fed with the signal from the double-cantilever beam gage used to measure displacement (ref. 6). The power supplies for the load cell and the clip gage did not drift more than 0.2 percent in an 8-hour period. The probable error in displacement gage output readings from the X-Y plot was ±0.00135 millivolt (≈0.023 percent of the total displacement measured). (This error was determined from 11 runs with the steel specimen in the round-hole clevis using 0.599-in.- (1.52-cm-) diam pins.)

Tests to determine the influence of loading-pin diameter were made using a short stiff loading train which was locked in place with respect to the upper and lower head of the tensile machine. The initial misalinement between the upper and lower loading trains did not exceed 1/32 inch (0.8 mm). (As described in LATERAL MISALINEMENT, measurements of opposite edge displacements on the aluminum specimen indicated this amount of initial misalinement to result in negligible bending.) In order to investigate the influence of lateral misalinement using the setup shown in figure 4, it was necessary to introduce universal joints between the special loading fixture and the heads of the machine.

In the series of tests made to determine influence of loading-pin diameters, a run consisted of loading the specimen to a fixed load (4000 lb (17 790 N) for the aluminum and 16 000 lb (71 170 N) for the steel specimen), and then unloading. Runs were made for three initial positions of the specimen in the clevis, designated as hanging free, pushed, and pulled. When hanging free, the specimen was allowed to assume its natural unloaded position (rotation of slot tip downward) permitted by the pin-to-hole clearances. When pushed or pulled, the specimen was displaced from its hanging-free position in a horizontal direction to the limits permitted by the pin-to-hole clearance. These movements were accomplished by light hand pressure which was maintained during the initial stages of loading. Pulling moved the specimen slot tip away from the loading pins, and pushing moved it toward the loading pins. These variations in initial position were intended to simulate the extremes of what might be encountered when installing the specimen in the clevises. A run was repeated, without removing the specimen from the clevis, at least two times for each combination of pin diameter and initial position.

The investigation of lateral misalinement (see fig. 4) made use of the aluminum specimen loaded through 0.580-inch- (1.47-cm-) diameter pins in the square-hole clevis. It was necessary to measure displacements on opposite edges of the specimen. For this purpose, two clip gages were matched by means of an adjustable-gain, direct-current amplifier in the output circuit of one gage. The correct setting was determined by matching the gage outputs at a given load, with the gages centered on the specimen. For the misalinement tests, these two gages were mounted on opposite edges of the specimen, and load-displacement records were made simultaneously on an X-Y-Y recorder. Replicate runs were made for each amount of misalinement of the clevis with respect to the loading train.

CONVENTIONAL CLEVIS RESULTS

Features of Load-Displacement Records

A schematic load-displacement record obtained with the round-hole clevis is shown in figure 5, which illustrates the salient features of such records and the way in which they are analyzed. The behavior shown is typical of that obtained for 0.590-inch (1.50-cm) pins corresponding to a clearance of 0.012 inch (0.31 mm).

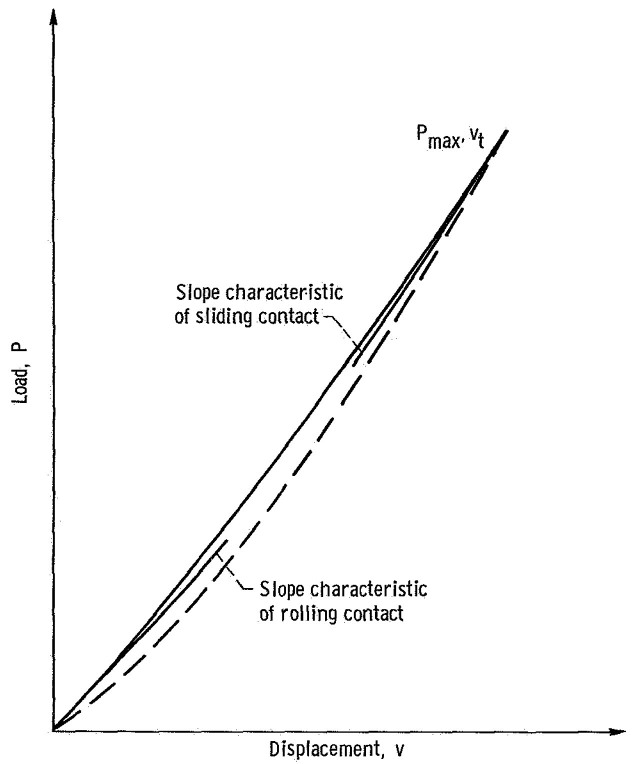


Figure 5. - Schematic load-displacement record illustrating behavior typical for transition from rolling to sliding contact between loading pin and hole surfaces.

The shape of the load-displacement record may be better understood by reference to the schematic diagram in figure 6, which shows the loading-pin movement in relation to the holes in the specimen and clevis. Rotation of the specimen end during loading tends to turn the loading pin in a direction which drives it toward the slot tip in relation to the loading axis OP. This motion, as indicated by the arrows, can take place by rolling contact until the contact point between the pin and clevis hole has shifted (toward the slot tip) sufficiently to provide a countertorque high enough to lock the pin. Further motion then takes place by sliding.

In the load-displacement record in figure 5, note that there is an initial linear portion of lowest slope and a final linear portion with the greatest slope. The initial linear portion is associated with the situation of rolling contact just described, while the final linear portion represents sliding contact, with the slope being increased by the frictional resistance to sliding. (This resistance is controlled by the friction coefficient, which depends on the particular combination of metals and surfaces involved.) The curved loading line then represents a transition between conditions of minimum friction associated with rolling contact and maximum friction associated with sliding. This transitional behavior disappears if the pin clearance is sufficiently large and is confined to a very

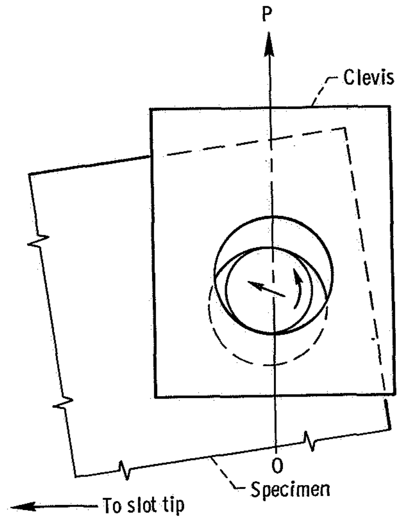


Figure 6. - Schematic of round-hole clevis and specimen, illustrating specimen and pin movement during loading. (Rotation of specimen end greatly exaggerated.)

small initial region of the loading line if the clearance is sufficiently small. Thus, linear loading lines can be obtained with either very loose or very tight pins. The total displacement at a given load is, of course, always reduced by friction effects. The effect of friction is also responsible for the hysteresis loop observed on unloading. However, the magnitude of this loop depends on the proportion of the total load range which is associated with sliding.

Effects of Pin Clearance on Total Displacement

The influence of pin clearance is best represented by plotting the ratio of the total displacement at maximum load (v_t in fig. 5) for each run to the average total displacement at maximum load v_o for the smallest pin diameter with the specimen hanging free. This displacement ratio is shown in figure 7 for the aluminum and steel specimens as a function of the relative clearance $\Delta D/D_p$, where ΔD is the difference between the specimen hole and the pin diameter D_p. The trend of the displacement ratio with decreasing relative clearance is similar for both specimens, and as might be expected, indicates an increasing contribution of friction as relative clearance decreases. For the tightest fits, the errors in load during a K_{Ic} test could be slightly over 10 percent. The influence of the relative clearance on v_t/v_o fades out for $\Delta D/D_p$ values greater than about 0.08. However, note that there is appreciable scatter between replicate runs for the larger clearances. This scatter is probably due to a small change in the effective a/W associated with random variations in the contact position of the pin with re-

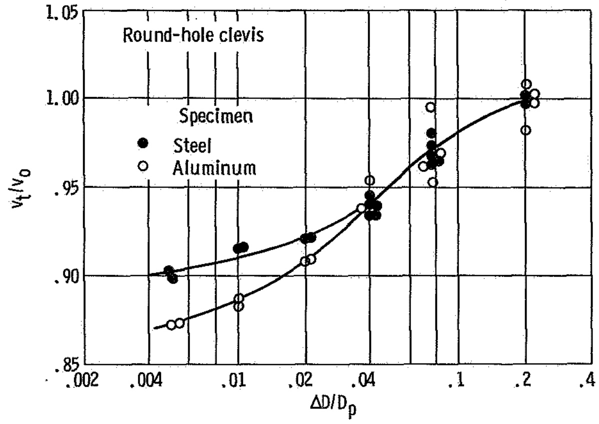


Figure 7. - Influence of relative clearance on displacement ratio for specimens loaded from hanging-free position in conventional round-hole clevis.

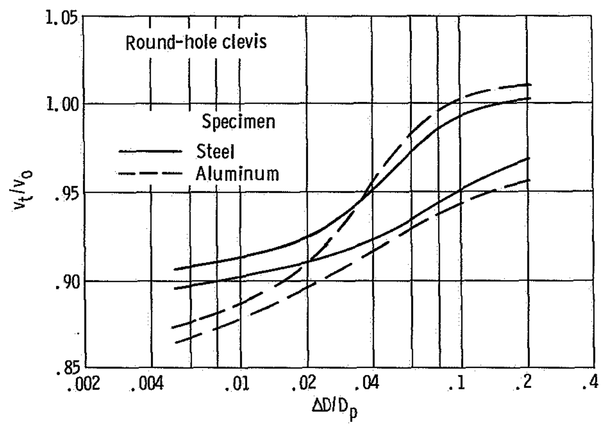


Figure 8. - Scatterbands for influence of relative clearance and three initial positions (hanging free, pushed, and pulled) on displacement ratio for specimens loaded in conventional round-hole clevis.

spect to the specimen and clevis hole. Possible variation in this position is larger for the larger clearances, and this is consistent with the greater scatter in v_t/v_o with increasing $\Delta D/D_p$. (A few runs were made using stepped pins with a 0.599-in. (1.52-cm) diameter to closely fit the specimen and a 0.500-in. (1.27-cm) diameter to give a clearance of 0.102 in. (2.59 mm) with the clevis holes. The results still showed scatter, presumably because the pins were not loaded consistently at the same point, which resulted in variations in a/W.)

In order to investigate extremes in the initial contact positions that might be encountered when installing a specimen in the round-hole clevis, the runs with various pin diameters were repeated, with the specimen being initially pushed or pulled to the extremes permitted by the pin clearance. These results, along with those from the hanging-free position, are shown in figure 8 for the aluminum and maraging steel specimens. There was no consistent effect of pushing or pulling in either lowering or raising the v_t/v_o values, and for that reason the spread of results has been represented by a scatterband. As might be expected, the effects of pushing or pulling faded out for the smallest clearances. The results indicate a possible spread in K_{Ic} values of about 5 percent might be encountered because of variations in the initial specimen setup, even though the pin clearances were sufficiently large to minimize friction effects.

Effects of Lubricants

Several different lubricants were tried in runs with the steel specimen and the round-hole clevis using a 0.599-inch- (1.52-cm-) diameter pin ($\Delta D/D_p = 0.005$). The results (table I) indicate all the lubricants increased the displacement ratios, and the

TABLE I. - INFLUENCE OF LUBRICANT ON DISPLACEMENT RATIO FOR STEEL SPECIMEN

[Round-hole clevis with 0.599-in. - (1.52-cm-) diam pins ($\Delta D/D_p = 0.005$).]

Lubricant type	Number of test runs	Displacement ratio, v_t/v_o	
		Range	Average
None	11	0.912 to 0.905	0.908
Teflon spray	6	.943 to .938	.941
Silicone spray	3	.931 to .927	.929
MoS_2 dry	4	.933 to .927	.931
MoS_2 + oil	3	.933 to .927	.931

largest effects appear to be associated with the Teflon spray. Comparing table I with figure 7 shows that this beneficial effect is small compared with the influence of increasing the relative clearance.

SQUARE-HOLE CLEVIS RESULTS

The results with the round-hole clevis indicated that if the pin clearances were sufficient to minimize friction effects, scatter in measured K_{Ic} values could be encountered because of uncertainties in the initial position of the specimen.

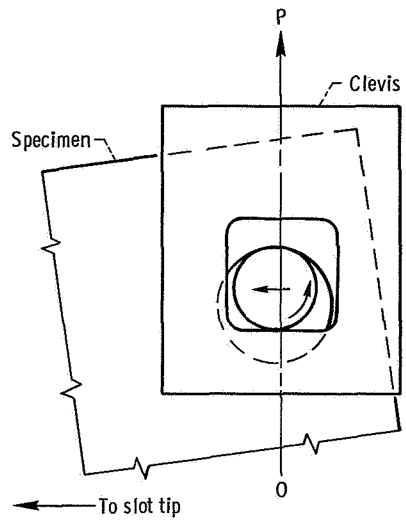


Figure 9. - Schematic of square-hole clevis and specimen, illustrating specimen and pin movement during loading. (Rotation of specimen end greatly exaggerated.)

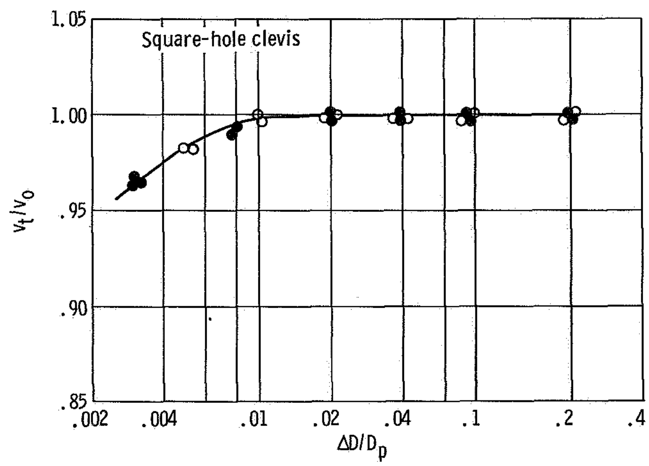


Figure 10. - Influence of relative clearance on displacement ratio for specimens loaded from hanging-free position in square-hole clevis.

A possible way around this difficulty is to provide a flat bearing surface in the clevis hole for the pin. A schematic of such a clevis design is shown in figure 9, which also shows the direction of pin movement during specimen loading. It is evident that pin translation can take place by rolling contact, with the pin being always loaded directly on a diameter. Thus, as contrasted with the round-hole clevis (fig. 6), the pin is free to roll unless it contacts the sides of the clevis hole.

Results for the square-hole clevis are given in figure 10 for the aluminum and steel specimens for an initial hanging-free position. Note that the displacement ratio is independent of the relative clearance above a $\Delta D/D_p$ value of about 0.01. For the tightest fit (smallest value of $\Delta D/D_p$) the displacement ratios are reduced by a few percent. This effect arises from the decreased compliance of the specimen associated with the pin filling the hole. Note that there is essentially no scatter in the data. Linear load-displacement records with no hysteresis on unloading were obtained for the aluminum specimen at $\Delta D/D_p$ values above 0.005. For the steel specimen, the corresponding value of $\Delta D/D_p$ was 0.019. At relative clearances smaller than these values, increasing amounts of nonlinearity appeared in the load-displacement records accompanied by very small hysteresis loops. The difference in behavior between the two specimens is probably associated with the larger amount of pin bending produced by the higher loads used with the steel specimen. Pin bending tends to use up the available clearance.

The results of pushing and pulling are shown in figure 11. The effect of pushing or pulling is to move the contact point between the pin and the specimen hole out of line with

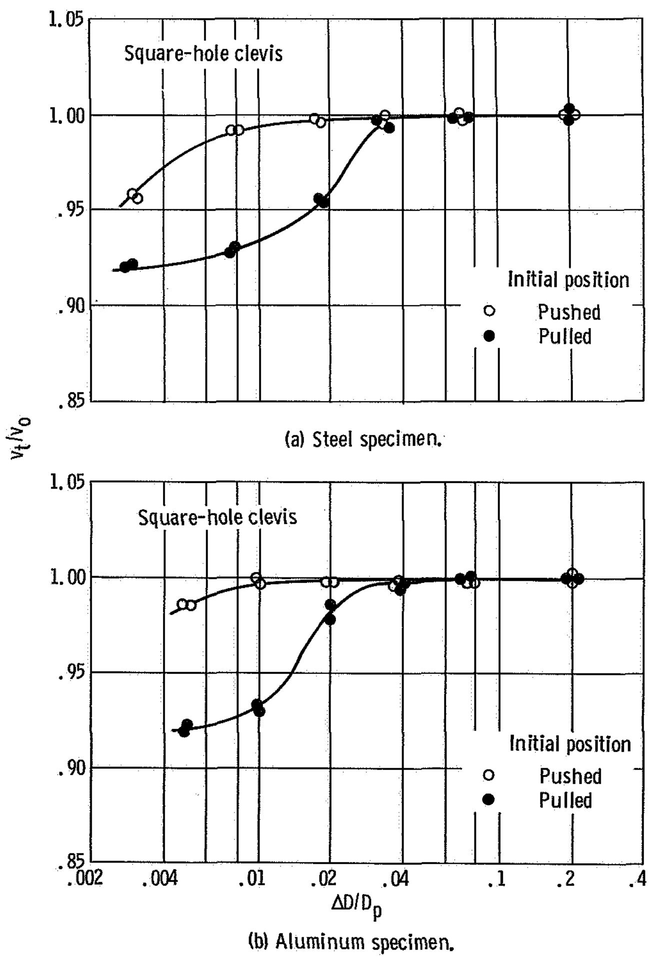


Figure 11. - Influence of relative clearance and initial position on displacement ratio for specimens loaded in square-hole clevis.

the load axis (OP in fig. 9) to the limits permitted by the pin clearance. In the case of pushing, this movement is in the opposite direction to that produced by specimen rotation during loading. Thus, as shown in figure 11, pushing has a negligible effect on v_t/v_o except for the smallest values of relative pin clearance because, upon loading, the pin moves away from the side of the clevis hole. Pulling, on the other hand, moves the pin to the limit in the same direction as that produced by specimen rotation during loading (i.e., to the clevis hole boundary toward the slot tip, see fig. 9). If the relative clearance $\Delta D/D_p$ is sufficiently small, the effect of pulling is to reduce the displacement. However, with sufficient clearance, this effect of pulling disappears. Thus, as the slack is removed during the start of a run with the specimen in the pulled position, the pin will roll away from the side of the clevis hole, and the contact point between the pin and the specimen will move toward the load axis. During loading, the pin rotation is reversed, and unless the clearance is sufficient the pin would again contact the side of the clevis hole. According to figure 11, a $\Delta D/D_p$ value of 0.04 provides for sufficient clearance to prevent this contact and, therefore, to eliminate the effect of pulling.

LATERAL MISALINEMENT

The influence of lateral misalinement obtained using the special loading device (fig. 4) was investigated for the aluminum specimen using the square-hole clevis and 0.580-inch- (1.47-cm-) diameter pins. To permit the specimen to experience the bending moments due to lateral misalinement it was necessary to load the misalinement fixture through universal joints rather than the short, stiff loading train used for the pin clearance studies.

The results of the misalinement tests are presented in figure 12 as the average edge displacement difference ratio $\Delta v/2v_o$ plotted against the lateral misalinement (see fig. 4). The quantity $\Delta v/2$ represents one-half the difference between the opposite edge displacements and, therefore, should approximate the maximum deviation in stress intensity from the specimen vertical centerline to either edge. The significance of this gradient in stress intensity during an actual fracture toughness test is not known. However, according to figure 12, a misalinement of 1/32 inch (0.8 mm) produces a gradient of about 1 percent, which should be negligible in its effect on K_{Ic} measured with a gage at the centerline. Strictly, the results apply only to the specimen thickness tested because the gradient would change with thickness. However, in our judgment there would be no practical advantage in calling for alinement better than 1/32 inch (0.8 mm).

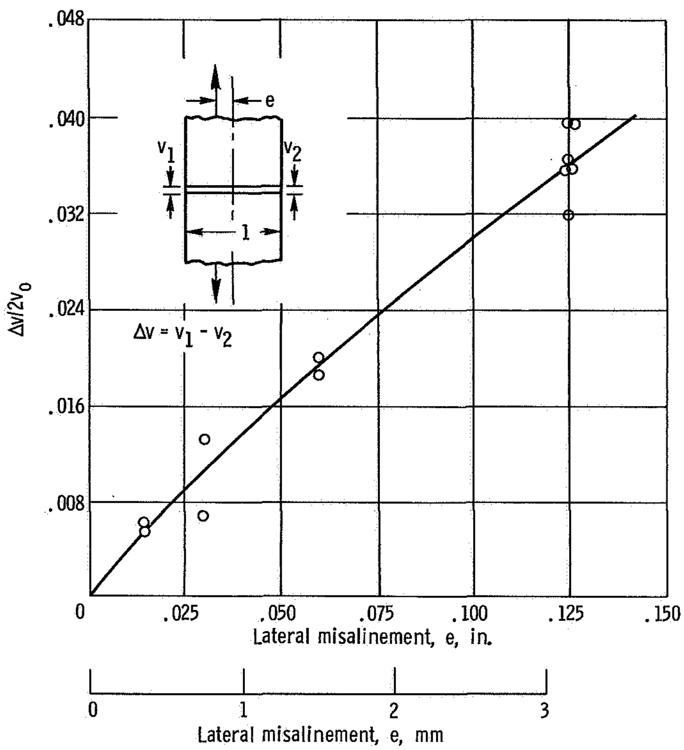
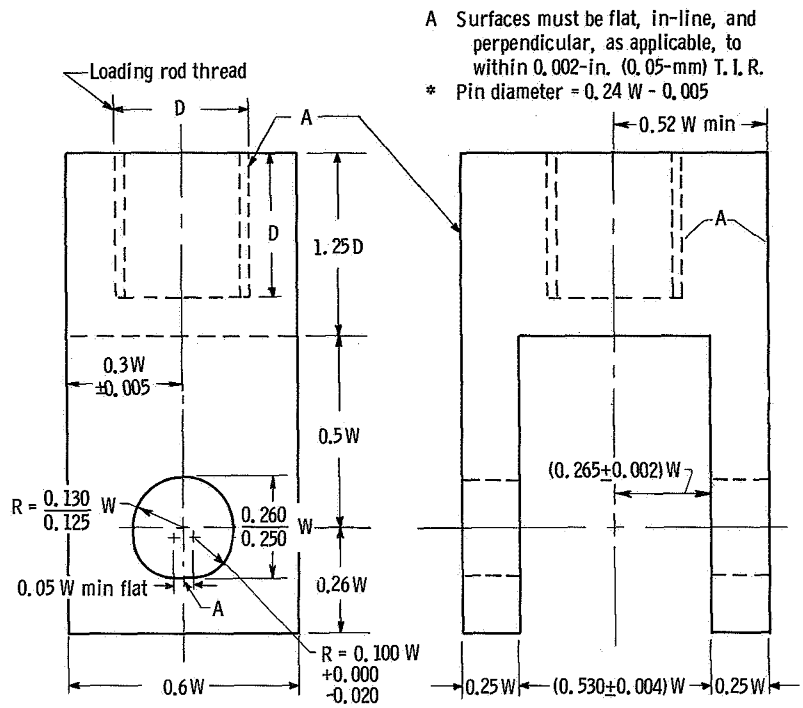


Figure 12. - Influence of lateral misalinement on average edge displacement difference ratio for aluminum specimen loaded in square-hole clevis using 0.580-inch (1.47-cm) loading pins.

RECOMMENDED CLEVIS DESIGN

On the basis of the results obtained in this investigation, it is evident that the undesirable effects of friction and the slight uncertainty in initial pin position associated with a round-hole clevis can be eliminated by producing a flat in the clevis for the pin bearing surface. The minimum size of the flat would be equal to ΔD. It should be joined smoothly to the clevis hole by a radius which is sufficiently small that the pin will stop against the straight sides of the hole rather than attempt to roll along the radius.

A clevis design which meets these requirements is shown in figure 13, which is dimensioned in terms of the specimen width W. The pin has been sized on the basis of the assumption that it is a beam loaded uniformly across 90 percent of its unsupported length and having free ends. Calculations made on this conservative basis show that the load-carrying capacity of the pin is limited by bending and that, if the pin yield strength is about 15 percent higher than that of the specimen, a 0.24 W pin will permit testing standard specimens (specimen width to thickness ratio, W/B = 2) which meet or exceed the size requirements specified for K_{Ic} determinations (ref. 7). The clevis has been designed to be stronger than the pin insofar as failure by yielding in tension or bearing is concerned.



U. S. Customary Units, in.	SI Equivalent Units, mm
0.005 .020	0.125 .508

Figure 13. - Tension testing clevis. (All tolerances in inches.)

A possible mode of clevis failure could be indentation of the clevis flats by the pin. This possibility was investigated by pressing a full-hard 300-grade 1/2-inch- (1.27-cm-) diameter pin into a 1/2-inch- (1.27-cm-) wide block of the same material. A maximum contact stress equal to about three times the yield strength produced an indentation less than 0.5-mil (0.127-mm) deep, which was judged to be insignificant in terms of the use of the clevis. On the basis of these tests, the pin would fail in bending well before the clevis flats were damaged by indentations.

It is recommended that both pins and clevises be made from fully aged 300-grade maraging steel. In this way, finish machining can be done in the solution-treated condition and can be followed by aging with negligible change in dimensions. For most tests at room temperature, a 300-grade maraging steel fixture of the design shown in figure 13 should be satisfactory. However, for tests on very-high-strength materials, where the specimen may be undersized for K_{Ic} determination, or for tests on specimens of $W/B > 2$, the proportions given in figure 13 may be inadequate. For such cases, the design should be reexamined in light of the expected loads. Tests at other than room temperature require further design considerations. These would include time-dependent strength changes at elevated temperatures and increased sensitivity to stress concentrations at low temperatures.

Lewis Research Center,
National Aeronautics and Space Administration,
Cleveland, Ohio, February 27, 1969,
731-25-03-09-22.

REFERENCES

1. Manjoine, M. J.: Biaxial Brittle Fracture Tests. J. Basic Eng., vol. 87, no. 2, June 1965, pp. 293-298.
2. Mostovoy, Sheldon; Crosley, P. B.; and Ripling, E. J.: Use of Crackline-Loaded Specimens for Measuring Plane-Strain Fracture Toughness. J. Materials, vol. 2, no. 3, Sept. 1967, pp. 661-681.
3. Srawley, J. E.; and Gross, Bernard: Stress Intensity Factors for Crackline-Loaded Edge-Crack Specimens. Materials Research & Standards, vol. 7, no. 4, Apr. 1967, pp. 155-162.
4. Pook, L. P.; and Dixon, J. R.: A Note on the Analysis of Single Edge Notch Tensile Specimens. Presented at Conference on Fracture Toughness, Sheffield, England, 1968.
5. Pook, L. P.: The Effect of Friction on Pin Jointed Single Edge Notch Tension Specimen. Int. J. Fracture Mech., vol. 4, no. 3, Sept. 1968, pp. 295-297.
6. Fisher, Douglas M.; Bubsey, Raymond T.; and Srawley, John E.: Design and Use of Displacement Gage for Crack-Extension Measurements. NASA TN D-3724, 1966.
7. Anon.: Proposed Recommended Practice for Plane-Strain Fracture Toughness Testing of High-Strength Metallic Materials Using a Fatigue-Cracked Bend Specimen. 1968 Book of ASTM Standards, Part 31, pp. 1018-1030.

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